COMPUTERS AND CREATIVITY

CAROLE SPEARIN McCAULEY

7 "IT'S AN ADVENTURE REALLY!"

You're at work in a large room. You've picked up the telephone and dialed long distance into the computer system to which the terminal—a specialized kind of typewriter in front of you—is connected. You "sign on"—type your password and the name of your project. The terminal types high-speed back at you that the computer is alerted and ready to TELL YOU ALL—maybe some statistics on how U.S. Senators have voted on different issues for a paper you're writing. (It will also sneak you baseball scores provided somebody has already entered them as "data.")

Stop!

"I've never worked with a computer or at a terminal. Math is my worst subject."

"I type like ten words a minute. Will the machine wait?"

"I'd like to learn a language to program a computer, but they want geniuses or logic freaks. Right?"

They laughed when I sat down at the terminal!

Some creative people—artists, scientists, or computer specialists—are geniuses. More often, however, they are ordinary humans with a fresh idea who acquire the skills to implement that idea. Suppose you want to make a film or paint pictures, write a story, or design some jewelry. How do you get started? How do you work with others? What happens if you switch from doing it as a hobby to doing it for a living?

Ken Knowlton and Lillian Schwartz do computer films and other picture processing at Bell Laboratories's large research center in Murray Hill, New Jersey, about an hour from Manhattan. Both are friendly people, enthusiastic about their work and experimentation in these visual art-sciences that are less than fifteen years old.

Ken Knowlton met me in the reception area of Bell and guided me down corridors and elevators to Lillian's office, where the interview began. She was surrounded by her film machines, reels, and photos. Both people were dressed informally—Ken in a striped shirt and grey trousers and Lillian in a black pantsuit and Navajo silver jewelry.

Interviewing continued across the corridor as Ken demonstrated the color control equipment ("joystick") and the electronic microfilm recorder. While this recorder plots points, a black blip begins to draw lines, rectangles, ellipses —a delightful kaleidoscope, a moving rainbow of red, green, blue, yellow—on two display tubes (tv screens). The recorder, which can film the results, is connected with a computer in the next room, visible through a picture window. Ken Knowlton is the author of four languages that program the computer and control and select the figures produced on screen by the microfilm recorder.

We completed the interview over sandwiches, milk, and coffee in Ken's office. It was well stocked with technical papers, books, posters, graph paper sketches of his latest ideas. His blackboard showed a flow chart diagram—the boxes, arrows, and human logic that precede a program for the computer.

Here are Lillian and Ken discussing their work and themselves as creative people in an unusual new field.

GETTING STARTED

HOW DID YOU GET INTERESTED IN COMPUTER FILMS AND PICTURE PROCESSING?

Ken: I've always been interested in movies—and computers. As a programmer, I was hired here at Bell Labs in the Computer Techniques Research Department.

Lillian: I was also interested in movies. I began as a sculptress and artist, which led me to a fascination with movement and space conceptualization. Computer films are the realization.

Ken studied engineering physics at Cornell and received his Ph.D. in communication sciences from MIT in 1962. He has taught computer graphics and computer art at the University of California, Santa Cruz. Lillian was a nurse before becoming an artist, sculptor, and filmmaker. Her work has appeared in over seventy exhibitions and film festivals.

WERE YOUR FIRST COMPUTER EXPERIMENTS ENCOURAGED?

Ken: You mean by my supervisors? Yes. At that time I wasn't doing anything that could be called "computer art." My very first movie was a dry, plodding exposition of the system by which it was made.

I'VE SEEN STILLS FROM THAT IN ONE OF YOUR ARTICLES.

Well, the movie itself is almost a still—it's such a drag.

THAT WAS ABOUT TEN YEARS AGO.

Yes. That was 1964. I came here in the fall of '62. That work was interesting because it was the first attempt anywhere to invent a computer language for making animated movies with simple diagrams, boxes, and text for instructional purposes.

THAT WAS YOUR FIRST COMPUTER LANGUAGE—BEFLIX (BELL FLICKS).

That's right.

The BEFLIX language describes a picture or diagram as an array of spots—46,368 or 252 × 184 of them exactly. Each spot is represented in the computer's storage memory by the numbers one to seven that indicate intensity of light at that point. A picture is built up like a mosaic and modified in the computer by manipulating these numbers. A comparison from analytic geometry is the process of taking a pencil and plotting a graph from some x- and y- coordinates. At inter-

vals the microfilm recorder is ordered to display and photograph the entire array of spots. BEFLIX contains 25 kinds of instructions that specify where and when to perform operations and how many frames to produce.

HAS FORMAL SCHOOLING HELPED OR HINDERED YOUR CREATIVE WORK?

Ken: Schooling which had to do strictly with computers clearly helped, although I didn't take that many courses. I've had a variety of schooling, all technical, in science and engineering, but it's hard to say exactly where and how it's influenced me.

Lillian: I had little formal schooling in art except for a few fine arts courses in drawing and art history. Most of my training has come from constant work in art as a sculptress and painter. I've discovered from teaching students that if you come to computer filmmaking with a basic knowledge of art principles, then form, structure, and knowledge of color are second nature to you. Your artistic techniques have been tested, and you can concentrate on all there is to learn about computers.

There is a problem with computer programmers who lack art training and yet produce so-called "computer art." They're not successful because they lack the background.

ONE BASIC THEORY OF THIS BOOK IS THAT CREATIVE USE OF COMPUTERS WILL HAPPEN ONLY IF THE PEOPLE USING THEM ARE CREATIVE.

Lillian: Right. I agree with that. . . . To be fair, however, I should allow for accident. Sometimes somebody who lacks art training but works long enough can develop something valid because of the nature of the tool. For example, if someone took one of Ken's programs and changed its parameters, the result would probably be something good.

Selectivity is also important—judging what to choose and use, what a good design is, how to combine it with color.

AND RANDOM-NUMBER GENERATION GIVES YOU A MASSIVE AMOUNT FROM WHICH TO SELECT.

Ken: It depends on how you use the random number generator. There are ways to use it that avoid 95 percent rubbish and only 5 percent good material. In fact, we've been able to use most of the film we've produced.

Lillian: Selectivity here leads to the evaluation of combinations—the process of making a collage, so to speak, of sound, image, line, design.

WORKING WITH OTHERS

The group dynamics of art dismays some people who enjoy and insist on solitude for some or all of the creative process. Ken Knowlton has achieved a nice balance between solitude and collaboration with others. He works alone to complete the computer programming and some scientific aspects of the work and cooperates with an artist on aesthetic questions. Lillian Schwartz worked alone at painting and sculpture before coming to Bell Laboratories.

IS YOUR WORK HERE A GROUP EFFORT OR DO YOU WORK MAINLY ALONE WITH YOUR OWN IDEAS?

Ken: On scientific things and computer programming I work mostly alone. Occasionally I work with one other person on a scientific project defined by me or by the two of us together. It's not a group project in the sense that somebody above us says, "This is your job. Now do it."

On computer art I've usually lacked the courage to work entirely alone.

YOU NEED AN ARTIST.

Ken: Yes. I've in fact worked with Stan Vanderbeek and now with Lillian as collaborators. I've very much trusted their judgment for the final form of the films.

Lillian: The artist grows with and into the artistic craft. The concrete basis of the craft shifts according to the medium, but the creative insight remains a constant. Ken is structured in terms of science; his insight is one of programming possibilities. This has its creative aspects, but it flows toward what he sees possible within the scientific framework as craft. Working together, I've gained empathy with Ken's scientific intuition and he has, I feel, released more creative insight.

Look at this drawing—a design for a test pattern. He completed it alone. It's a good job, but sometimes he won't recognize this until somebody tells him.

Ken: You're saying if I didn't have to bother doing science, I wouldn't need artists. Some people tell me the opposite—if I'd just get rid of my artists, I could do some science.

Lillian: Of course, any artist can't work with just any scientist. In computer art, compatibility is extremely important. We strive for structured outbursts, you might say, rather than a disjointed output. When I came, I knew nothing about computers, for example, and he explained so much to me.

YOU SEEM TO ENJOY CONSIDERABLE FREEDOM HERE. WORKING FOR A LARGE CORPORATION IS A GOOD EXPERIENCE FOR YOU.

Ken: Yes and no. There's ambivalence among the supervision here about whether our work is a good thing and whether I should be doing so much of it.

WORK METHODS

Techniques to acquire an idea and implement it vary vastly among creative people. Accidents, fantasies, frustrations with self or equipment, pressure from others in the same field, tensions, failures—all the ordinary impediments of living affect the work for better or worse. With luck, they provide incentive to create.

HOW DOES AN IDEA FOR A PROJECT OR TECHNIQUE COME TO YOU?

Ken: No idea. I never thought about it.

Lillian: I have fantasies and dreams.

Ken: You're kidding! . . . About how you're next going to relate to the computer?

Lillian: Sometimes the images themselves direct me.

DO YOU ALLOW FOR AN ACCIDENT IN YOUR WORK?

Lillian: Yes. Accidents are extremely useful if they're directed toward a comprehensive goal.

Ken: No. I don't allow for accident. I use the random-number generator deliberately because I want some effects or decisions made for me. For example, if there are five hundred small design decisions that must be made and it really doesn't matter how I make them except that the final result should have some statistical property, then I'm happy to let a random-number generator decide. But if it's clear that I've made a human error in programming and the result comes out differently from what it should be, that annoys me.

Lillian: It doesn't annoy me. I get some fantastic effects from that sort of thing. The accident is assimilated into the art.

WHAT IS YOUR WORK SCHEDULE? DO YOU THINK ABOUT WORK ONLY DURING SET HOURS OR IS IT ALWAYS GOING ON IN YOUR HEAD?

Ken: Nine to five. But I also work on projects, make drawings at home. Occasionally I come here on a weekend.

Lillian: My work doesn't stop.

DO DREAMS, DAYDREAMS, OR FANTASIES AFFECT YOUR WORK?

Ken: I'm sure they do, but I can't say how. When I close my eyes or rub them, I see images of colors, checkerboards, patterns. I want to make pictures of them.

AND YOU'VE NEVER HAD MIGRAINE HEADACHES? BECAUSE THAT WOULD GIVE YOU MUCH NEW VISUAL PHENOMENA, ABERRATIONS, TO PLAY WITH.

Ken: No. . . . I like to look at things, watch squirrels out the kitchen window, fires, waterfalls. I sat for hours in California and watched the clouds come off the ocean, form and billow over the mountains.

Lillian: Did it go farther? Did you wonder how you would interpret that with a computer?

Ken: I never wanted to use a computer to copy natural things. For example, if I devoted myself to creating an artificial environment, I could have the computer produce a whole live action scene on three sides of me—wind blowing, waves crashing—simulating a beach scene. Now why artificially create an environment that already exists? Why not go sit on the damn beach in the first place?

Lillian: But an artist would create it to envelop other people in a beach experience. The beach is open to a universal meaning. When expressed through the chosen craft, perhaps it can reach what is universal in each person. Otherwise people could sit on a beach and maybe miss all but a few of its aspects.

Ken: Then there's something wrong with the world if people can't see and can't feel. . . . *Take* them to the beach then—it's much less expensive than having the computer create one!

I'VE CONSIDERED YOUR POINT IN REGARD TO COMPUTER MUSIC. THERE'S NO POINT IN USING THE COMPUTER AND THE MOOG SYNTHESIZER TO REPRODUCE BEETHOVEN, FOR EXAMPLE.

Ken: Unless you can do it in a new way. Now Walter Carlos had done Bach in essentially new form that justifies his using the Moog synthesizer.

IS YOUR WORK LIFE CONTINUOUS OR SEGMENTED? DO YOU SEE YOUR WORK ENERGY COMING FROM ONE ONGOING CREATIVE PROCESS OR FROM SPECIFIC MOMENTS OF INTUITION THAT CAN RADICALLY ALTER WHAT YOU DO?

Ken: I occasionally get insights, very specific ideas, times when I invent something. An idea comes in perhaps a few seconds. It then requires *much* development to check it out. Sometimes my ideas aren't work-related at all. For instance, I'm making a new kind of table tennis and devising new ideas for games.

But I never sit down and say, "Now I'm going to have an idea." That would be pointless. I'm never short of ideas. Rather the problem is sifting them and figuring out which to work on.

Lillian: My ideas come when I'm already involved in work on something else. They seem continuous. I see something which leads me in a different direction. I want to tackle the new idea instead of completing the original project, but this would mean many beginnings and no development of anything. If the new idea proves valid, however, I can return to it later.

Ken: I have another version of this—the notion that if I *could* do such and such, it would be just great. I begin to work and immediately discover all kinds of problems so additional ideas are needed in the form of solutions to problems. For instance, I may decide it would be nice to be able to superimpose one image on another to allow a new perception of the relationship between the controls of an instrument and the picture it generates. Once I decide *what* to do, the problem becomes *how*—a problem of geometry and optics, where to place the mirrors and lenses, lights or buttons in order to carry out the notion.

Another example: it's a great idea to make movies by computer. I have a machine that will put lines or spots of light on a screen. The problem becomes how to control these thousands of spots and lines to make intelligible pictures. Then it becomes work, a process of shifting, juggling, finding solutions that are workable, feasible, understandable.

DO YOU FEEL WHAT'S NEEDED IS MORE OR REFINED EQUIPMENT THAT WILL LET YOU CONTROL MORE VARIABLES?

Better equipment, yes. I sometimes work on equipment if I get a particular idea of how a picture phone, for example, may be used to help my present experiments. But my field is mostly software, programs for the computer, rather than hardware. I also translate my subroutines into standard computer languages, such as FORTRAN, to allow more people to use them for graphics work.

ARE YOU HAPPY WITH PRESENT EQUIPMENT? YOU SAID YOU NEEDED A TV TUBE, FOR EXAMPLE, THAT WOULD PRODUCE BETTER COLORS FOR PHOTOGRAPHY?

I'm never totally happy with equipment. The computer should always be faster or larger, should be able to generate pictures in real time. The TV picture tube should be larger to allow finer resolution, better colors.

DOES YOUR WORK STEM FROM A CHALLENGE YOU'VE SET YOURSELF, SOMETHING YOU PROVE TO YOURSELF?

Ken: My *ultimate* goal is to win my mother's approval.

WELL DONE, GOOD AND FAITHFUL SERVANT!

Lillian: I don't have an ultimate goal. I work always in the present. I have short-term technical goals concerned with finishing projects that involve, for instance, choosing the right film stock, filters, or exposures to use. . . . If I made a statement about ultimate goals today, I probably wouldn't agree with it tomorrow.

HOW DO PERSONAL TENSIONS OR MOODS AFFECT YOUR WORK? FOR EXAMPLE, HOW DO YOU MEET DISCOURAGEMENT OR DEPRESSION?

Ken: What? . . . Me discouraged?

Lillian: Well, I can tell you. He sits in the corner over there.

Ken: I don't do much about it. I just keep working.

Lillian: And I keep working. I don't sit in a corner, but if I'm depressed and know the work will suffer or won't be the calibre I want, then I do something comparable to an artist's stretching canvases or a writer's typing business letters. I get out of it. Ken, you get out of it by keypunching cards for the computer.

Ken: No comment.

HOW DO YOU EVALUATE YOUR OWN WORK PROGRESS?

Ken: I guess I see whether other people like it. I'm not sure that's a good way. During the first forty years of my life, I spent a lot of energy trying to please people. I'm going to spend the next forty trying to shake them up a bit—or at least not caring so much about their reactions.

Lillian: That means you've reached the stage when the outside world doesn't matter or you don't need it so much. Of course, the outside world is the audience. Their reactions to the art can aid its development or its destruction. The craft can be changed according to external inputs; creativity itself involves hypersensitivity toward the craft, its function, its relation to society. Yet the final judgment is not just one of previous outside reactions but faith in one's ability and instinct as an artist.

Ken: Well, to some extent I always need external response to know that I'm alive, that I'm not living in a fantasy.

THEN YOU DON'T SAY, FOR INSTANCE, BY NEXT YEAR I'LL HAVE A PARTICULAR PROJECT ALL COMPLETED?

Ken: Oh yes, I do. I work on projects that are sufficiently large—a system for making a film that simulates the movement of atoms, molecules, crystals by drawing ball-and-stick models. It involves a large programming job, much checking out, many trials with small lengths of film. A time schedule is involved; it would be nice to show it, for instance, at a meeting of chemists six months from now.

Without such a time and effort structure, my ideas slide. I don't finish them. I've wanted, for example, to play chess with the computer. I have some notions of how I can win, but so far I haven't tried them out. I've never set up a schedule for it.

Another idea that intrigues me is the four-color problem—the question of coloring geographical maps. Does there exist a map that *needs* five colors so that no two adjacent countries are the same color? So far, four colors seem to be enough, but nobody ever really proved that. Mathematicians have knocked their heads against this brick wall for a hundred years.

I REMEMBER THINKING ABOUT THIS PROBLEM WHEN I USED TO DRAW HISTORY MAPS IN JUNIOR HIGH.

Yes. You can easily prove that five colors are enough, but nobody's yet demonstrated a map that needs five colors—that adjacencies of countries will trap you into requiring a fifth. So far in human experience there's always been a way to recolor what you've already drawn with four colors. Maybe there's a way to apply the computer to this—either by making a five-color map or by proving conclusively you don't need one.

HOW DO YOU EVALUATE YOUR OWN WORK PROGRESS, LILLIAN?

I'm very hard on myself. I don't have goals of "next year." It's more like "next *week* I must finish." Last week when I was sick, I said, "I have to work." Ken asked why and I answered, "I have to. That's all." Creativity is existence—it's not only the poet who lives each day and dies each night.

DO YOU FEEL PRESSURED BY WHAT OTHER PEOPLE IN THIS FIELD ARE DOING?

Lillian: No, although this doesn't preclude keen awareness of their work.

Ken: Yes. In anything I want to do the best or the first. It's very disappointing to come in a close second because my work would seem unnecessary. For example, if somebody else devises a system for making movies of molecules that's as good or better than mine, and sooner, that would mean I've wasted a lot of time. *I* want the recognition for having worked hard. I already lost out on one thing that makes me slightly angry.

Lillian: On what?

Ken: On "my" 19-face unistable polyhedron. That's a 3-dimensional geometrical construction designed in a certain way so that it's unstable on all faces except the bottom one. No matter which face you put it on, it will roll to the next, the next, and the next until it finally reaches the bottom. Someone had already demonstrated that it was possible to make such a thing; then somebody else was able to demonstrate one with forty-three faces. Now, as the number of faces decreases, it will be chunkier and chunkier, more likely to be stable on more than one face. The search was for one with a *minimum* number of faces. Just to reduce the figure to nineteen three years ago was a tremendous improvement.

AND YOU CALCULATED THIS BY COMPUTER WITHOUT EVER ACTUALLY BUILDING THE THING.

Yes. . . . So I submitted my paper for publication and in the process learned Richard Guy at the University of Calgary had discovered it two months earlier and already had his paper ready for publication. So it's *his* now forever more.

Lillian: And you don't have any inner satisfaction from it?

Ken: Well, yes. I say that we independently discovered the same thing.

Lillian: I think this process happens constantly—a simple, logical idea may be lying there but it requires the right person to come along and recognize how to use it.

Ken: But the science of polyhedra and regular bodies is very highly developed. Now it even includes the Great Inverted Retrosnub-icosidodecahedron.

Lillian: Say that again!

SOUNDS LIKE AN EXTINCT BIRD.

Ken: And please be sure to distinguish it from the *Small* Inverted Retrosnub-icosidodecahedron. . . .

Polyhedra are solid, three-dimensional figures with many sides. The icosidodecahedron has 32 sides.

DO YOU SEE A CONNECTION BETWEEN YOUR WORK AND ARTIFICIAL INTELLIGENCE?

Ken: I'm interested in artificial intelligence. If I get into chess playing, I'll be into something I'd call artificial intelligence. I don't use that term much because it's a splashy melodramatic word that really should be defined in terms of a specific application. Most people who say they're working in artificial intelligence are working on a specific project. Usually they're working up gimmicks in a particular area and really not addressing themselves to the larger question of what intelligence means.

I SEE YOUR WORK AS MORE RELATED TO AUTOMATION—DOING

RAPIDLY BY COMPUTER WHAT USED TO BE TEDIOUS WORK OF DRAWING FIGURES AND DESIGNS BY HAND.

Lillian: But a lot of these things never existed.

Ken: Right. There are two different problems here. One is processes that were done by hand and can now be done better or faster by computer. The other is processes that were never done until the computer made them possible. I'm more interested in the second—what was never done before.

So what if you can do something faster? What difference does it make unless you're learning something profoundly significant? I'm not interested in "automation" if it means putting people out of jobs because that requires social and economic reorganization.

CAN YOU MENTION A FEW THINGS NEVER DONE BEFORE THAT YOU'RE WORKING ON? IS YOUR MOVIE ON ATOMS AND MOLECULES AN EXAMPLE?

Ken: Yes. And other kinds of movies that consist, for instance, in tens of thousands of black and white dots in particular relationships to one another. Before the computer, you just couldn't make that kind of movie.

An electronic microfilm recorder can plot points and draw lines a million times faster than a human draftsman. This machine and the computer that controls it make feasible some kinds of movies that would have been prohibitively intricate, time-consuming, and expensive to draw and film.

The recorder consists of a display tube and a camera, and it understands only simple instructions such as those for advancing the film, displaying a spot or letter, drawing a straight line from one point to another. Though this repertoire is simple, the machine can compose complicated pictures from many basic elements; it can draw 10,000 to 100,000 points, lines, or characters per second.

The speed, ease, and economy of computer animation permit the moviemaker to take several tries at a scene—producing a whole family of film clips—from which he chooses the most appealing, a luxury never before possible.

THE SHEER LABOR TO CALCULATE AND DRAW THE DESIGNS BY HAND WOULD BE OVERWHELMING. . . . DO YOU INTEND YOUR FILMS MAINLY FOR CLASSROOM INSTRUCTION?

Ken: Yes, if they involve subject matter not done previously or not done well—my chemistry films, for example. However, I'm more interested in new visual effects, patterns and sequences. It's an adventure really. I tremendously enjoy other people's computer films and things done by video synthesizer. I'm fascinated with whatever is new, splashy, delightful, intricate on the visual scene. Because of the sheer amount of calculation the computer can do, it can blend symmetries, periodicities, randomness and thus produce truly new results.

ART AND THE PUBLIC

At some point most creative people desire feedback—to discover whether and how their work has affected others. Lillian and Ken question each other on which of their projects they would continue even if no one saw or approved. They also compare other people's films with their own.

DO YOU SPEND MUCH TIME AT COMMERCIAL MOVIES?

Ken: Not too much.

Lillian: I see a lot of films, three or four a day sometimes during my lull periods. If I walk around New York City, I end up at the movies.

ARE YOU WATCHING COLOR OR CAMERA TECHNIQUE?

Lillian: No. I enter hoping it will be a great experience. If I catch myself watching technique, I feel the film hasn't succeeded. If I've enjoyed the film emotionally, then I return to view it technically. I've seen *Cries and Whispers* twice, for instance. I responded violently the first time; even the second time I stopped watching technique and began to respond again. There aren't many films that can absorb me throughout them. I usually begin to edit. . . .

Ken, do you get as much satisfaction from your computer-generated films that are aesthetic in purpose rather than scientific? Or does the scientific give you more pleasure? I mean the final result rather than the making, which involves mostly technical decisions.

Ken: The two kinds of films—and their audiences—give me different things. They complement each other. The scientific films provide one kind of adventure, and audiences differ. Scientists can be a grim bunch with whom it's fun to talk technically but association doesn't go much beyond that.

A couple of conferences stand out in my mind. Those were seminars with artists—interactive panel discussions with lively people. I knew the other participants sufficiently that we could communicate about real issues. When college audiences and young faculty are intrigued with my films, that's exciting. It's fun to find out how what we do here relates to them, how people feel about art and machines and themselves.

Lillian: If you didn't receive positive feedback, would you continue work in films and graphics?

Ken: I probably wouldn't. . . . Would you?

Lillian: Yes. If I felt a project had validity for me.

Ken: I guess I lack the courage of Van Gogh or other painters who persisted a lifetime without recognition. . . . I would probably change direction. For example, these little diagrams on graph paper are the beginning of devising regular ways to divide a plane into areas—regular, semiregular, random—according to rules. I believe there are many ways to define the rules; which I choose will determine what kind of structure I get.

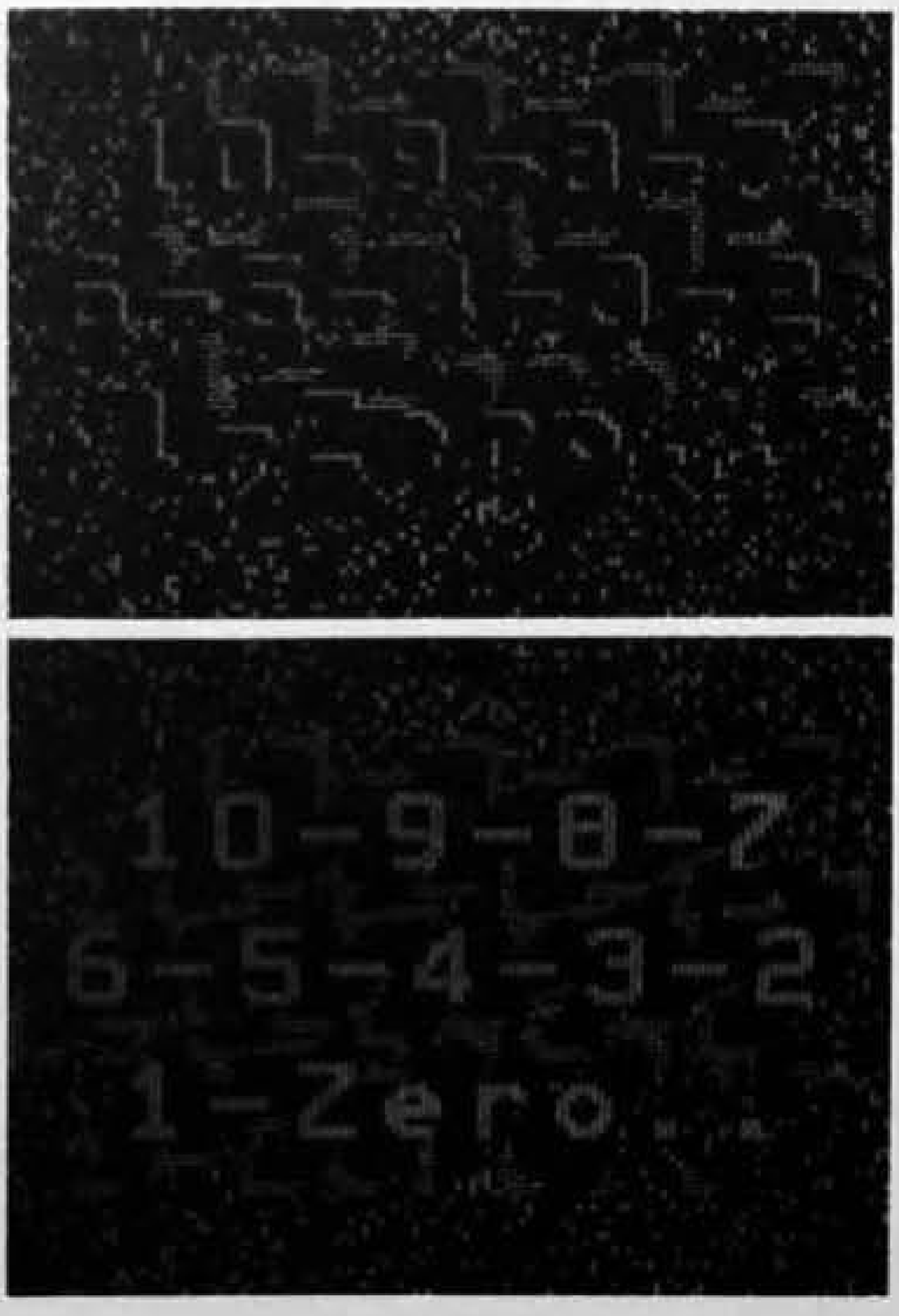
Lillian: Suppose somebody came along and said, "This is trash." Would you throw it out?

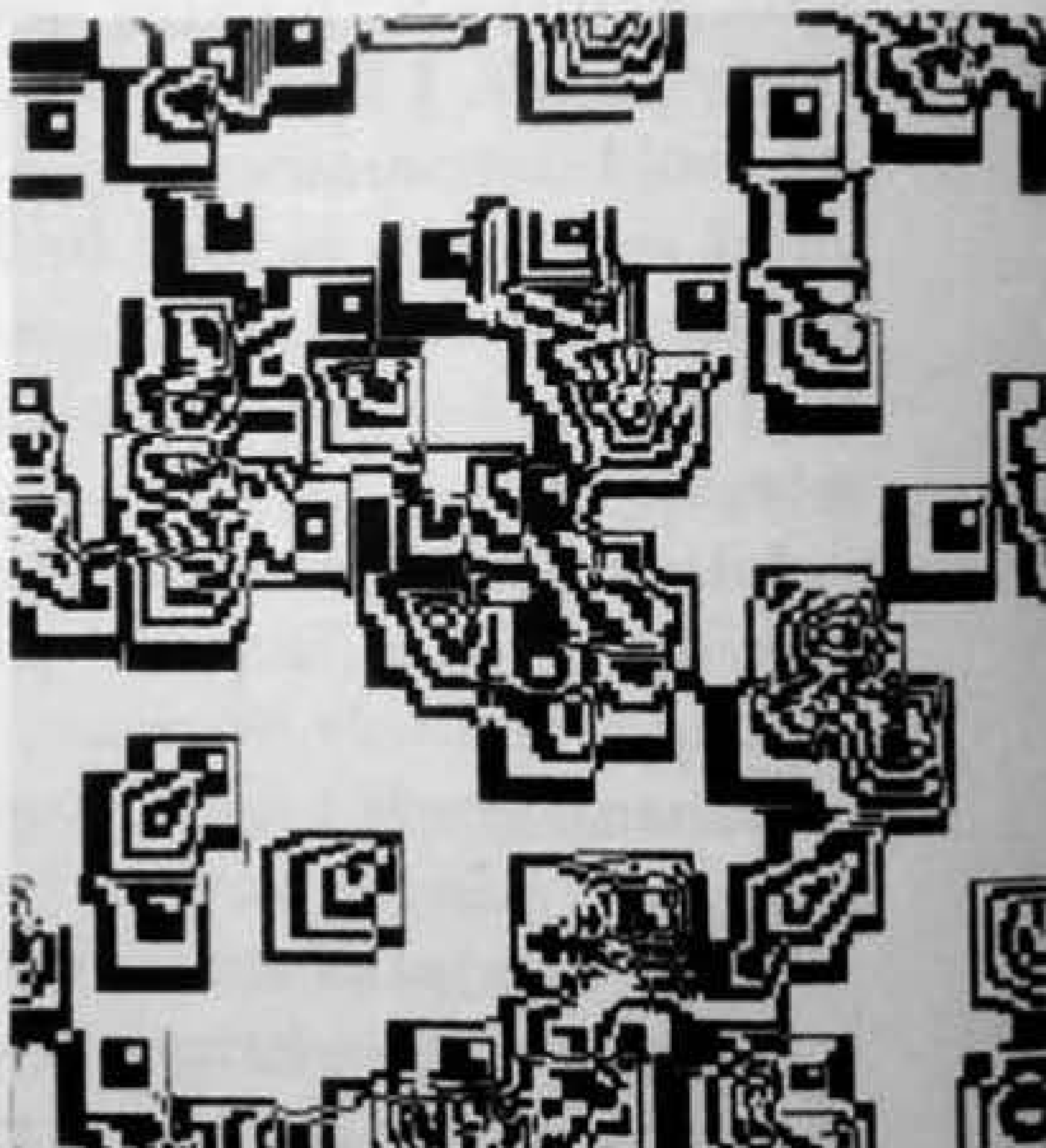
Ken: No. Because it's fun, it's therapeutic. And I realize better than he does how many ways this exercise can be done.

Lillian: You just changed your mind! . . . So you would continue working. You wouldn't discover public opinion in the middle of this project anyway. You would already have finished it and begun your next idea.

Ken: Well, if I consider public acceptance, nobody ever wrote me from an art or computer science department and requested a copy of TARPS, but 35 schools have written to Santa Cruz asking about EXPLOR. So naturally, I think, I'm more excited about EXPLOR.

TARPS, EXPLOR, and L^6 are the other computer programming languages by Ken Knowlton. See Fig. 18 for an





18 Examples of computer graphics produced with Ken Knowlton's TARPS language (*left*). Text is printed in "B" characters that follow a diagonal path downward and to the left, then to the right and upward to the center.

19 Overlapping contoured squares produced with EXPLOR language (*right*). This is a frame from the film *Pixillation*, produced by Lillian Schwartz and Ken Knowlton for AT&T.

example of TARPS and Fig. 19 for work done with EXPLOR. EXPLOR can produce still or moving images and do picture processing by coding and photographing arrays of spots, as with the BEFLIX language.

As Ken indicates, the audience for experimental computer films is assembling, especially around New York and in colleges and universities.

The Schwartz-Knowlton films have already won a variety of prizes, including the Ciné Gold Eagle and awards from Computers and People Magazine *and Ann Arbor Film Festival. In 1971 one of Lillian's films was chosen to represent the United States at the Montreal Film Festival and International Film Festival (Germany). The Museum of Modern Art and the Whitney Museum, New York City, have both shown a series of the films.*

On page 154 you can find a list of Schwartz-Knowlton films on loan for private or school use.

As you see, Lillian and Ken conducted their own interview toward the end. Later they admitted the process showed them some aspects of each other's work and methods that they hadn't realized before!